PROCEEDINGS OF
THE SEVENTH JAPAN- U.S. WORKSHOP
ON GLOBAL CHANGE

PRECIPITATION SYSTEMS/PROCESSES AND
THEIR VARIABILITY
IN THE ASIAN PACIFIC REGION

November 16-18, 1999
Tokyo, Japan

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Joint Report

U.S.-Japan Workshop on Global Change
Report of the Co-Chairs

This workshop was the seventh in a series of U.S.-Japan Workshops on Global Change Research held under the framework of the *U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology*. These workshops contribute to the implementation of global change research activities, fostered by the scientists of Japan and the United States, through information exchanges and discussions which promote long-term collaborations that benefit society.

The seventh U.S.-Japan Workshop focused on the topic of *Precipitation Systems/Processes and Their Variability in the Asian Pacific Region.* The Workshop was held at the SEAVANS in Tokyo, Japan on November 16-18, 1999.

Seventy individuals participated in the Workshop, including researchers, scientists, and science managers from universities, government agencies and ministries, and national institutions of both Japan and the United States. Participants were asked to articulate what is known, what is not known, and what Japan and the United States should do in the years ahead in the area of precipitation processes and their variability in the region. In particular, they aimed to focus their discussions on critical unanswered questions. As the Co-convenor's report which follows shows, they were largely successful in answering this charge and identified ten major recommendations for collaboration in areas in which Japanese and American scientists can work together to address many of the difficult questions affecting the global climate.

The Workshop was sponsored by the Science and Technology Agency of Japan (STA) and the U.S. Global Change Research Program (USGCRP). Preparations and coordination was carried out in cooperation with the Frontier Research System for Global Change (FRSGC) in Japan and the U.S. National Science Foundation (NSF). The Co-chairs would like to acknowledge the work of the staff in these organizations for their efforts in ensuring a worthwhile and productive workshop.

Taroh Matsuno
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Frontier Research System for Global Change

Dr. Robert Corell
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Subcommittee on Global Change Research
Committee on Environmental and Natural Resource

Report of the Co-Convenors

Introduction

Precipitation is crucial for life, agriculture and the economy, particularly in the Asia-Pacific region which is home to more than 60% of the world's population. One of the most important natural disasters affecting this region is the occurrence of floods and droughts associated with fluctuations of the monsoon climate. Summertime floods in the East Asian-Japan region are mostly associated with heavy precipitation and development of mesoscale convection within the Mei-yu/Baiu front, which are affected by variability in the large-scale monsoon climate. The monsoon climate is in turn influenced by fluctuations of sea surface temperature over the Indo-Pacific basin, e.g., the El Niño/Southern Oscillation (ENSO), and variabilities of snow cover and soil moisture over the Asiatic continent. Therefore, in order to provide a better understanding of precipitation processes and their impacts on Asian-Pacific climate, an integrated approach involving coordinated studies of the atmosphere, ocean, and land processes is essential. In addition, interannual and inter-decadal climate variabilities of the North American continent is also closely associated with that of the ENSO-monsoon system through atmospheric teleconnections.

The 7th Japan-U.S.Workshop on Global Change focused on various aspects of precipitation and hydrological processes, and their variability in the Asia-Pacific region, particularly that associated with the ENSO/monsoon system. During the first day plenary session of the workshop, scientists from Japan and the U.S. discussed a wide range of scientific issues relating to meso-scale processes leading to heavy precipitation in the East Asian monsoon region and in the United States; dynamical processes regulating monsoon precipitation; monsoon-El Niño relationships; coupled land-atmosphere processes; remote sensing of precipitation, snow and soil moisture; development of special data sets useful for monsoon studies; long-term trends in Asian Pacific rainfall and their possible relationship to decadal to multi-decadal variability and trends. These issues were further discussed within the four working groups sessions: I. Modeling Clouds, Heavy Precipitation and Land-Surface Processes; II. ENSO-Monsoon Processes; III. Satellite Mission Issues (2005 and beyond); and IV. Long-Term Climate Variability and Precipitation. In addition, there was an ad-hoc discussion on the joint Japan-U.S. effort in the Coordinated Enhanced Observation Period (CEOP)—a new first international initiative project under the WCRP (World Climate Research Programme) involving intensive process/monitoring studies of the global and regional hydrologic cycles in the atmosphere-land-ocean climate system.

Major Recommendations

These recommendations are summaries taken from the individual working group reports which contain more detailed discussions of the recommendations as well as relevant issues.

1. The CEOP plan for a coordinated experiment in the Asia/Australia monsoon region should include a significant Japan-U.S. cooperative effort which incorporates the ocean processes as well as land-hydrology, atmosphere components. In this regard it was recommended that the implementation plan for the CEOP regional monsoon experiment include the Western Pacific and Equatorial Indian Ocean. It was further recommended that this portion of the CEOP plan should be developed within the CLIVAR Monsoon Panel during its session scheduled for December 1999.

2. Conduct joint studies on monsoon-ENSO interaction over the Indo-Pacific warm pool region
   -- Hold a joint Japan-U.S. workshop focusing on observation and model intercomparison studies of the Asian-Pacific region and in conjunction with AMIP, CMIP modeling activities
   -- Develop a modeling and diagnostic plan in conjunction with the CEOP implementation plan for the A-A monsoon region.

3. Conduct studies of the observed relationship between northern hemisphere land surface processes (snow cover, soil moisture and vegetation) and Asian monsoon rainfall variability.
   -- Develop long-term in-situ surface data sets of soil moisture, snow cover, and run-off/river discharge
   -- Develop global satellite land surface data sets in conjunction with ISLSCP-II/GSWP-II.

4. Perform observational studies and high-resolution cloud and land-atmosphere interaction simulations with an area larger than 40,000 km^2. Run models for weeks and longer and validate using forcing functions data derived from recent field campaigns in the monsoon region (e.g., SCSMEX, JASMINE, and GAME/CEOP reference sites).

5. Develop cloud system/landscape resolving models which include hydrological/ecological components to investigate precipitation systems, ground water, river discharges and other land-atmosphere interaction issues, over the East Asian continent, by using the Earth Simulator. Model intercomparisons similar to PILPS should be carried out.

6. Carry out modeling and diagnostic studies to understand the horizontal and vertical transport of aerosol, trace gases, momentum and water vapor associated with Asian Pacific climatic features (e.g., Baiu front, subtropical high), including the interaction with cloud systems.

7. Continue the development of multi-satellite, in-situ, blended global precipitation data sets with high spatial and temporal resolutions (e.g., 1^{o} x 1^{o} , daily or 3-hourly), e.g. from TRMM, and from operational satellites as initiated by GPCP, for monsoon-ENSO modeling and diagnostic studies.

8. Reconstruct and archive long-term climatic records of precipitation, temperature, soil moisture, land cover, snow cover and other monsoon hydrologic parameters, based on both instrument observations and paleoclimate data.

9. Develop improved physical and radiactive transfer models relevant to remote sensing of the hydrological cycle, as well as the development and multispectral application of data assimilation techniques in order to effectively utilize a wide variety of in situ and remote sensing observations.

10. It is strongly recommended that the development of joint Japan-U.S. satellite missions and related technology to provide (a) high temporal resolution, global observations of precipitation, and (b) robust global observations of hydrological variables over diverse

surface types, be continued. These efforts should focus on the proposed GPM/ATMOS-A1 mission and on future sensor development for soil moisture and snow cover measurements beyond the capability of AMSR.

Points of Contact

Recommendation 1 (CEOP WG)	Japan: Koike	US: Leese
Recommendation 2 (WGII)	Japan:Yasunari	US: Lau/Wang
Recommendation 3 (WGII)	Japan: Oki	US: Robock/Vinnikov*
Recommendation 4 (WGI)	Japan: Fujiyoshi/Saito	US: Moncrieff
Recommendation 5 (WGI)	Japan: Iwasaki/Sugi*	US: Pielke/Xue/Sud
Recommendation 6 (WGI, IV)	Japan: Yoshizaki/Uyeda	US: Wakimoto/Sud
Recommendation 7 (WGII, III)	Japan: Inoue/Nakazawa*	US: Gruber/Adler
Recommendation 8 (WGIV)	Japan: Matsumoto/Tada	US: Mehta/Robock
Recommendation 9 (WGIII)	Japan: Nakamura	US: Petty
Recommendation 10 (WGIII)	Japan: Nakamura	US: Adler

*Did not participate in the workshop, but contact information is included in the participants list.

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Section II

Working Group I: Modeling Cloud, Heavy Precipitation and Land-Surface Processes

Participants: T. Iwasaki (Co-chair), R. Pielke, Sr. (Co-chair), Y. Fujiyoshi (Vice Co-chair), K. Kuma, J. Leese, T. Matsuno, M. Moncrieff, M. Murakami, H. Niino, K. Ninomiya, A. Numaguchi, K. Saito, Y. Sud, H. Uyeda, R. Wakimoto, Y. Xue, M. Yoshizaki

Scientific Issues

The integration of atmosphere, ocean and land surface processes is essential in order to advance our understanding of precipitation associated with the Asian-Pacific climate. Major science issues include the role of cloud-radiation feedbacks, understanding and documentation of mesoscale cloud systems, biogeochemical-biophysical-atmospheric interactions, ocean-atmosphere exchange processes and snow-monsoon interactions. Regional anthropogenic effects such as landscape change (e.g. tropical deforestation) and aerosol emissions also influence the climate in this region.

To enhance collaboration between the United States and Japanese scientists, the Japanese Earth Simulator will be a powerful tool to solve many modeling issues. For exploiting this computer resource most efficiently for global change studies, collaboration is recommended in a variety of forms. Enhanced U.S.-Japan cooperation in field observation projects, for example, will lead to a better understanding of smaller-scale cloud/precipitation systems which have different characteristics depending on geographical locations.

Data/Modeling Issues

1. Modeling issues: Continuous efforts are needed to improve the models. For example, we need to determine what are the climatically important space and time scales, and processes associated with cloud, boundary layer and surface effects. We also need to determine what level of detail is needed to properly represent sub-grid scale processes in a climate context. Specific model needs include:

    (i) Atmospheric general circulation models and/or coupled atmosphere-ocean-land global climate models with comprehensive physics parameterizations for assessing weather and climate processes.

    (ii) High resolution global models with explicit representations of mesoscale cloud systems.

    (iii) Regional climate models for detailed descriptions of coupled mesoscale atmospheric-land surface-ocean processes.

    (iv) Cloud resolving models (CRM) to simulate cloud system processes explicitly.

2. Data issues:

(i) Additional observational platforms, for example, research aircraft, including airborne Doppler radar; multi-parameter radar; boundary layer radar; and cloud radar should be implemented. Beneficial collaboration between the U.S. and Japan could maximize the scientific accomplishments.

(ii) Aggregation and desegregation of the spatial scales of the observed and model data, including 4-D data assimilation, need to be explored.

Programmatic Issues

1. GCSS is an important activity under WCRP charged with understanding the physics of cloud systems mainly through a CRM approach, and improving the representation of cloud systems in regional climate models and GCMs.

2. BAHC is a committee in the IGBP which is developing improved land surface parameterizations and data sets for use in regional models and GCMs.

3. Data for global 3-D distribution of clouds are important to assess the water and energy budget of the earth. Space-based cloud profiling radar is strongly recommended to obtain the data (TRMM and GPM, CloudSat, Atmos-B1).

Recommendations for Japan-U.S. Collaboration

1. **Perform observational studies and explicit high-resolution cloud system and landscape resolving simulations with areas larger than 40,000 km^2, run for weeks and longer.** *(Japan: Fujiyoshi, Saito, Yoshizaki, Uyeda, U.S.: Moncrieff, Sud, Wakimoto)*

   These simulations should use, for example, forcing specified from SCSMEX, JASMINE and selected GEWEX/GAME/CEOP reference sites, and compare with single-column models run with the same forcing and with observations. Specific regions of interests are the West Pacific warm pool, East Pacific, Baiu front, Tibetan Plateau, cold air outbreaks over the Sea of Japan and the North Pacific. Coordinated ground-based and *in-situ* measurements should be performed during the Baiu season and winter season for detailed analysis of mesoscale and cloud system processes and use in the explicit high resolution simulations.

   In preparation for the cloud system/landscape resolving GCM to be run on the Earth Simulator, run global models at 20 km, 30 km, and coarser grids and compare with high resolution simulations subjected to large-scale forcing specified from the global model.

2. **Develop cloud system/landscape resolving GSMs which include hydrological/ecological components to investigate precipitation systems, cloud/precipitation systems, ground water, river discharges and other land-atmosphere interaction issues over the East Asia continent by using the Earth Simulator.** *(Japan: Iwasaki, Sugi*, U.S.: Pielke, Xue)*

This includes, for example, a biogeochemical land surface module as part of the global model in order to assess the role of increased CO_2 on transpiration and vegetation dynamics, and the subsequent feedback to the climate system, including clouds and precipitation. Also recommended are anthropogenic land use change experiments using the global model to investigate the role of landscape on climate under current atmospheric conditions.

3. **Carry out modeling and diagnostic studies to understand the horizontal and vertical transport of aerosol, trace gases, momentum and water vapor associated with Asian Pacific climatic features (e.g., Baiu front, subtropical high), including the interaction with cloud systems.** *(Japan: Numaguchi, U.S.: Moncrieff, Sud)*

Implement, for example, a convective momentum transport (CMT) parameterization in the Earth Simulator and compare with a control run (no CMT), to assess the impacts on mean (Hadley/Walker) circulations, and on convectively driven transients in the tropics.

* Did not participated in the workshop, but contact information is included in the participants list.

Working Group II: ENSO-Monsoon Processes

Participants: T. Yasunari (Co-chair), B. Wang (Co-chair), M. Hishida, A. Kitoh, W. Lau, T. Oki, A. Robock, H. Ueda, P. Webster, A. Yatagai

This working group was concerned with the intraseasonal-to-interdecadal variability of the ENSO-monsoon system and the physical processes responsible for the variability and predictability.

Scientific Issues

A number of critical scientific questions/issues are identified in the area of monsoon-ENSO system study. Those include the following.

- What are the basic coupled modes (basin-scale and regional modes) of the interannual variability of the ENSO-monsoon system? And what are the impacts of these modes on Asian monsoon variability and predictability?

- What are the nature of the warm pool atmosphere-ocean interaction and impacts on the Asian monsoon variability?

- What are the observed relationships between Northern Hemisphere land surface processes (snow cover, soil moisture, vegetation) and Asian monsoon rainfall variability? And how well do model-simulated snow cover/soil moisture/monsoon relationships actually represent the observations?

- What are the impacts of warming trends (interdecadal variations) of the global circulation on the ENSO-monsoon variability?

- How can we better describe and determine the causes of the regionality, seasonality, and abrupt change of the ENSO-monsoon system? What determines the variability and relationship of the atmospheric heat sources (sinks) over land and ocean?

- What are the roles of the intraseasonal oscillation in seasonal and interannual variation of the ENSO-monsoon system?

- How does ENSO affect South Asian and East Asian summer monsoon rainfall? How do the monsoon and the tropical-extratropical interaction affect ENSO?

Data/Modeling Issues

To address the science questions listed above, it is important to have adequate observations and numerical models. This group discussed issues concerning the data sets and modeling relevant to the monsoon-ENSO studies. The following fundamental needs in data development are recognized:

- Long-term global high resolution reanalysis data sets, e.g., ERA-40, NCEP-2;
- Satellite and in-situ blended global precipitation data set (e.g., GPCP, CMAP); high spatial-temporal special TRMM rainfall (e.g., 1x1 degree daily precipitation);

· Archives/rescue long-term data and continuous monitoring of precipitation, soil moisture, snow, vegetation, and runoff;

· Estimates of long-term land/ocean surface energy fluxes and state variables.

We also identified the following urgent needs in model development:

· Improvement of simulation of Asian monsoon, in particular the monsoon circulation in the East Asian and western North Pacific regions (e.g., Baiu/Meiyu front, ITCZ, Subtropical High).

· Improvement of coupled model representation of the atmosphere-ocean interaction in the warm pool.

· Improvement of model representation of land surface processes, including snow and soil freezing processes.

Programmatic Issues

There are a number of programs that need collaboration and continuing support: CEOP; GSWP-II; CLIVAR WGSIP, AMIP II diagnostic subprojects on East Asian summer monsoon, soil moisture, and precipitation. More specific discussion of collaboration is presented along with recommendation for joint US-Japan effort.

Recommendations for Japan-U.S. Collaboration

The discussions resulted in the following two major recommendations.

1. Joint monsoon-(Indo-Pacific) warm pool-ENSO interaction study

(Japan: Yasunari, US: Lau/ Wang)

The Indo-Pacific warm pool is a key region for monsoon to influence ENSO variability and predictability especially during the turnabout and transition phases of ENSO cycle. The Asian monsoon is sensitive to SST variation in that region. In the western Pacific sector, there exists strongest signal of tropical-extratropical interaction. In addition, the warm pool region exhibits interdecadal variations that are coherent with those in the East Asian monsoon and the North Pacific Ocean. Therefore study the climate variability in the warm pool and the roles of the warm pool in monsoon-ENSO interaction is vitally important. For these reasons, a joint US-Japan program focusing on the Indo-Pacific warm pool climate study is highly recommended.

To establish this joint program, the working group made two further specific recommendations.

· Develop a joint modeling and diagnostic work plan in conjunction with the implementation plan for JASMINE/CEOP in the western Pacific and equatorial Indian Ocean, to be developed in CLIVAR Monsoon Panel meeting in December 1999.

· Hold a joint workshop focussing on observational study and numerical modeling/intercomparison of the East Asian-western Pacific monsoon and ENSO–monsoon interaction is recommended for year 2000 at IPRC. Members of AMIP 2 and CMIP modeling groups and diagnostic subprojects related to monsoon and ENSO variations will be invited, to coordinate assessment of AGCM simulations and needs for model improvements.

2. Study of the observed relationships between Northern Hemisphere land surface processes (snow cover, soil moisture, vegetation) and Asian monsoon rainfall variability *(Japan: T. Oki, US: Robock/Vinnikov*)*

- Long-term data sets are vitally important for such studies. Thus, we recommend continued data rescue and data archive efforts, specifically to gather soil moisture, snow cover (extent and depth), and runoff/river discharge data for Asia. In addition, continuation of long-term soil moisture observational programs, specifically in Russia, Mongolia, China, and India, and assembly, quality control, and distribution of the data, should be supported by the US and Japan.

- To obtain global land surface "data sets" of soil moisture and snow, remote sensing combined with land surface modeling will be necessary. Thus we encourage the development of microwave and other techniques from satellites to measure soil moisture and snow. These satellite products will have to be combined with in situ data and models for calibration and validation. Therefore, projects like GSWP II, PILPS Phase 2, and AMIP 2, with current and future US and Japanese participation, are important to these efforts.

- A project to study the relationship of snow cover anomalies to soil moisture anomalies, using existing data sets, should be started, specifically addressing how long a memory exists in the system, and what the predominant spatial patterns are. In addition, the relationship of snow cover and soil moisture anomalies to summer monsoon precipitation and circulation should be carried out, taking into consideration that there are several ways to characterize the timing and strength of the monsoon. This study must also take into consideration sea surface temperature patterns associated with ENSO and the warm pool regions.

In addition to the above major recommendations, this working group feels that the following item is also very important:

Satellite precipitation dataset development. To assess the quality of reanalysis (e.g., ERA, NCAR/NCEP) precipitation products, independent satellite data products are needed. We encourage existing projects and continuation of these activities into the future. Joint use of surface, reanalysis, and satellite products is necessary to produce the most reliable precipitation estimates to evaluate monsoon variations.

*Did not participate in the workshop, but contact information is included in the participants list.

Working Group III: Satellite Mission Issues (2005 and beyond)

Participants: K. Nakamura (Co-chair), G. Petty (Co-chair), R. Adler, K.Aonashi, L. Brown, T.Inoue, T. Koike, R. Oki, Y. Takayabu

Scientific Issues

Interannual and decadal scale variability of precipitation patterns in the Asian Pacific region are thought to be a manifestation of land-atmosphere and ocean-atmosphere interactions. For the study of these interactions, cloud cover, precipitation, moisture convergence, soil moisture, snow cover, sea surface temperature, etc., must be observed on spatial scales from local to global and on temporal scales from at least diurnal to decadal, with uniform quality and accuracy. It goes without saying that only a comprehensive program of long-term satellite and surface observations, integrated via modern data assimilation techniques, can satisfy this requirement.

Recent years have seen considerable progress in this area. One of the most notable examples is the Tropical Rainfall Measuring Mission (TRMM), which has demonstrated not only a number of significant technological improvements in the observing of precipitation from space but also the profound benefits, indeed necessity, of international cooperation in scientific undertakings of this magnitude.

In the case of TRMM, this cooperation has been crucial to activities ranging from the assembly and launch of the sensor hardware to the design and execution of field validation experiments. An additional benefit of immeasurable value to the climate research community has been the unprecedented free exchange of data, expertise, and research results, irrespective of national jurisdictions. Similar cooperative efforts between the U.S. and Japan are already well underway in preparation for the launch of ADEOS-II AMSR and Aqua AMSR-E instruments and the Global Precipitation/ ATMOS-A1 mission, which is proposed as a follow-on to TRMM.

Despite the outstanding progress that has been made in the study of precipitation and related processes on all scales, there remain important unmet needs. Although there will continue to be a role for research by individual scientists and institutions, it is clear that the scope and complexity of the scientific questions and corresponding measurement requirements demands an even larger role for joint U.S.-Japan satellite missions and science projects in the future.

This WG has identified for special emphasis the following basic scientific issues pertaining to the satellite monitoring of precipitation processes:

- The need for better detection and characterization of interannual variability and trends in precipitation patterns and amounts. This implies a requirement for new satellite missions with enhanced coverage and capabilities, couple with improved algorithms.

- The need to reliably infer fundamental – but for the most part unobservable – processes and properties (e.g., 4-D distributions of latent heating) from satellite measurements of other variables. This implies a growing reliance on sophisticated models and data assimilation techniques in addition to denser satellite observations.

- The opportunity to use satellite observations to validate and substantially improve some aspects of the above models, including parameterizations of cloud microphysical and radiative processses.

- The necessity of improved characterization of physical and statistical errors and uncertainties in satellite-derived products utilized in climate research, notwithstanding the absence, in some cases, of suitable in situ validation data.

Recommendations for Japan-U.S. Collaboration

With the above general issues in mind, and with a view to our charge to include consideration of long-term issues (2005 and beyond), the WG makes the following major recommendations:

1. It is strongly recommended that the development of joint U.S.-Japan satellite missions and related technology to provide (a) high temporal resolution, global observations of precipitation, and (b) robust global observations of surface hydrological variables over diverse surface types, be continued. These efforts should focus on the proposed GPM/ATMOS-A1 mission and on future sensor development for soil moisture and snow cover measurements beyond the capability of AMSR. *(Japan: Nakamura, US: Adler)*

2. National funding agencies should encourage joint research activities that focus on developing improved physical and radiative transfer models relevant to remote sensing of the hydrological cycle, as well as the development and application of data assimilation techniques in order to effectively utilize the wide variety of in situ and multispectral remote sensing observations presently available and planned for the future. *(Japan: Aonashi, US: Petty)*

In addition, the WG makes the following important, more specific recommendations:

3. We specifically urge bilateral support for new satellite missions that will address important deficiencies in both the coverage and quality of precipitation and moisture observations from space, especially as regards (a) temporal sampling of global precipitation, (b) reliable determination of precipitation amounts over land and other problem surface types, (c) globally robust observations of surface hydrological variables, such as soil moisture and snow cover. The proposed Global Precipitation Mission/ ATMOS-A1 is a clear example of such a mission. *(Japan: Nakamura, US: Adler)*

4. The improvement of microphysical and radiative transfer models relevant to satellite remote sensing and data assimilation is a complex task requiring major theoretical and observational efforts. Bilateral initiatives to address these problems should be encouraged. *(Japan: Aonashi, US: Petty)*

5. We recommend joint efforts to further develop multi-sensor, multi-spectral techniques: (1) Satellite radar observations have been shown in TRMM to be crucial to understanding the structure of precipitating cloud systems and should therefore be included in future satellite missions as part of an overall strategy for global precipitation estimation. (2) Efforts should continue to utilize multiple satellites to provide high time-resolution estimates of precipitation. (3) The benefits of including

visible/IR radiometers and lightning sensors aboard future precipitation missions should be considered when planning such missions. *(Japan: Inoue, US: Adler)*

6. The integration and interpretation of global, multi-sensor data sets requires advanced data assimilation techniques and the capability to access and process large data sets. Therefore we encourage agencies in both countries to support the development of the necessary capabilities and of appropriate data assimilation techniques. *(Japan: R. Oki, US: Hou)*

7. Many satellite and in situ data sets collected for operational purposes are also useful for global change research. Furthermore, many applications require timely access to these data sets. Therefore, operational and space agencies in both the U.S. and Japan are encouraged to make relevant operational data sets readily and expeditiously accessible to scientific users. *(Japan: Nakamura , US: Brown)*

Working Group IV: Long-Term Climate Variability and Precipitation

Participants: J. Matsumoto (Co-chair), A. Gruber (Co-chair), J. Hamada, H. Isobe, M. Kimoto, V. Mehta, C. Sucher, M. Yamanaka, N. Yamazaki

Introduction

Working Group IV was charged with determining the highest priorities presently facing scientists studying long-term climate variability and precipitation in the Asia-Pacific region. To focus the discussion, the phrase "long-term" was defined as inter-annual and longer, with the emphasis on timescales of more than ten years. It was also agreed that the discussions could not be limited only to the western-Pacific monsoon as the various regional climate systems are intrinsically linked.

Many common themes, concerns and suggestions pervaded presentations by the participants. These were discussed at length and are summarized in the following sections of this report.

Scientific Issues

The Working Group identified the following as key scientific issues:

(1) Understanding natural variability of precipitation at decadal and longer timescales in the Asia-Pacific region with an emphasis on the Asian monsoon precipitation regime.

(2) Understanding the interaction between natural and anthropogenic variability in the Asia-Pacific region as well as how these processes interact with each other and affect annual and interannual variability in this region.

Data/Modeling Issues

(1) Acquisition of long-term series of high density (both spacially and temporally), high quality precipitation and other data such as soil moisture, snow cover, vegetation, run-off as well as meta data.

(2) Merging *in situ* and remote sensing records and development of homogeneous time series for study of long-term climate variability.

(3) Integration of paleoclimate and instrumental data to create spatial and temporal time series on decadal and centennial time scales. Particularly important is the need to focus analyses on extreme climate events that may not be evident in the historical climate record.

(4) Free and open availability of relevant data for use by the scientific community.

(5) The hydrological cycle and land-atmosphere interactions need to be better represented in re-analysis data in order to enable quantitative diagnostics of long-term climate variability.

(6) Climate simulation models fail to represent temporal and spatial scales necessary for adequately predicting precipitation events in Asian monsoon systems such as Baiu frontal disturbances and monsoon depressions. This information is critical to understanding long-term climate variability.

Programmatic Issues

Coordination of long-term observing system strategies and data bases, both *in situ* and satellite (remote sensing), including CEOP, WCRP/GEWEX, IGBP, etc. directed toward precipitation processes in the Asian monsoon regime.

Recommendations for Japan-U.S. Collaboration

Working Group IV recommends:

(1) Mining existing data archives of precipitation and related parameters (including soil moisture, snow cover, vegetation, run-off, and oceanic data) and merging them with more recent satellite data to create homogeneous, long-term time series for use in climate variability studies. Specific suggestions include a joint workshop for planning endeavors such as digitization of historical precipitation records, reprocessing archived datasets, centralized distribution and procedures for merging satellite and *in situ* observations.
(Japan:Matsumoto, Yamanaka, US: Gruber, Mehta)

(2) The intercalibration of various data sets relevant to the Asian Pacific region, including paleoclimate proxy data. To facilitate this, a workshop involving both the global change and paleoclimate communities is suggested in order to determine how paleoclimate proxy records can be best combined with historical and observational records. Specifically, the workshop should focus on the most beneficial ways to combine paleoclimate proxy data with instrumental records and address issues such as precision, temporal resolution, and the identification of specific time periods representing climate extremes.
(Japan:Tada, US: Overpeck)*

(3) The coordinated validation efforts of climate model simulations on synoptic timescales in the Asian monsoon area, where average rainfall is dominated by intermittent heavy rainfall events. *(Japan:Kimoto, US: Mehta)*

(4) Working Group IV recognizes the importance of CEOP in advancing our understanding of climate variability in the Asian Pacific region. We recommend that the U.S. and Japan jointly plan the continuation, maintenance and expansion of CEOP Reference Sites in the GAME area. *(Japan:Koike, Yasunari, US: Leese)*

*Did not participate in the workshop, but contact information is included in the participants list.

Ad Hoc Working Group on CEOP
(Coordinated Enhanced Observing Period)

Participants: T. Koike, W. Lau, J. Leese, M. Yamanaka, T. Yasunari

The Workshop was informed of the current state of planning for the Coordinated Enhanced Observing Period (CEOP) which is part of the World Climate Research Programme (WCRP). The CEOP will consist of a two-year Data Collection Phase in 2001 and 2002 followed by a three-year Principal Research Phase.

The goal of CEOP is,
"To understand and model the influence of continental hydroclimate processes on the predictability of global atmospheric circulation and changes in water resources, with a particular focus on the heat source and sink regions that drive and modify the climate system and anomalies."
Within this overall scientific framework, the CEOP has set as one of its scientific objectives – to conduct a coordinated experiment in the Asian-Australian monsoon region as a major research activity in one of the significant heat source and sink regions that drive and modify the global climate system.

The Workshop participants expressed their strong positive views for the unique opportunities offered by the CEOP to conduct cooperative research by the US-Japan scientists within the framework of the World Climate Research Program. The plans for CEOP were discussed within each of the working groups in terms of the specific research opportunities which could benefit from the CEOP. These discussions resulted in a number of recommendations for improvements and participation in the CEOP. Those included the following.

- The CEOP plan for a coordinated experiment in the Asia/Australia monsoon region should include a significant Japan-U.S. cooperative effort which incorporates the ocean as well as the land-hydrology, atmosphere components. In this regard it was recommended that the implementation plan for this CEOP regional experiment include the Western Pacific and Equatorial Indian Ocean. It was further recommended that this portion of the CEOP plan should be developed within the CLIVAR Monsoon Panel during its session scheduled for December 1999.

- The CEOP plans for the Data Collection Phase in 2001 – 2002 includes the compilation of Reference Site Data Sets for applications to land area-hydrology and atmosphere coupling issues. The workshop participants recommended that the CEOP plans also include the data needed to perform Cloud-Resolving Model (CRM) simulations for those Reference Site Domains larger than 40,000 sq. km and for time periods of weeks or longer. It was further recommended that these data sets include the capability to compare the CRM output with the output from single column models as well as with observations.

- The CEOP plans to include satellite remote sensing products to evaluate their applications globally, especially for those regions with a sparsity of land-based in-situ observations. It was strongly recommended that the CEOP Data Collection Phase and the launch schedule for new satellite sensors (e.g., AMSR and AMSR-E) be coordinated in order to obtain information on precipitation, soil moisture, snow and related variables. This will assure that a full suite of in situ and remote sensed data is available to improve microphysical models and to provide global validation for the satellites.

- The CEOP plans to compile data sets from Reference Sites distributed around the globe will provide research quality data sets during the two-year CEOP data collection period that will be most valuable for the process studies and modeling planned during the subsequent CEOP Research Phase. The workshop participants recommended that the Japan-U.S. Representatives on the GEWEX Hydrometeorology Panel develop plans for future operation of these Reference Site data collection efforts as well as the other observing system capabilities installed during the course of each of the GHP Continental Scale Experiments.

Appendices

Appendix A: Program Agenda

7th Japan-U.S. Workshop on Global Change
"Precipitation Systems/Processes and Their Variability in the Asian Pacific Region"
November 16-18, 1999
SEAVANS, Tokyo, Japan

Agenda

Tuesday, November 16

9:00 a.m. Breakfast (Room 1: SEAVANS Meeting Room, 1F)

9:30 Plenary Session (Room 1):

Welcoming Remarks: Mr. Yoshiro Miki (Deputy Director-General, Minister's Secretariat, Science and Technology Agency (STA))

Opening Remarks: Dr. Robert Corell (Chair of the NSTC/CENR, Sub-committee on Global Change Research (SGCR))

Logistic Information Ms. Sawada (Staff of the workshop)

10:00 Plenary Session _(Session Chair : Dr. Yasunari)

Science Overview: (WG-I) Modeling Cloud, Heavy Precipitation and Land-Surface Processes

Prof. Kozo Ninomiya
"Mesoscale Characteristic of the Intense Rainfalls in the East Asia Summer Monsoon"

10:20 Dr. Roger Wakimoto
"Mesoscale Systems, Severe Storms, and Heavy Precipitation"

10:40 Discussion

11:00 Break

11:20 Dr. Yongkang Xue
"Modeling Land Surface-Atmosphere Interactions in East Asia"

11:40 Mr. Ken-ichi Kuma
"The Development of Global Land-Atmosphere coupled Model under NWP Environment with International Science Community"

12:00 p.m. Discussion

12:20 Lunch (see attached suggestions)

13:30 Plenary Session (Cont.) (Session Chair: Dr. Lau)

Science Overview: (WG-II) ENSO-Monsoon Processes (including CEOP)

Prof. Tetsuzo Yasunari
"Current Issues on ENSO/Monsoon Interactions"

13:50 Dr. Peter Webster
"The Indian Ocean and the Monsoon as a Coupled Ocean-Atmosphere Phenomena: The Modulation of Monsoon Precipitation"

14:10 Discussion

14:30 Plenary Session (Cont.)

Science Overview: (WG-III) Satellite Mission Issues (2005 and beyond)

Dr. Robert Adler
"Satellite-based Global Precipitation Data Sets at Monthly and Finer Time Scales"

14:50	Prof. Toshio Koike *"Microwave Remote Sensing of Snow, Soil Moisture, Surface Temperature and Rain"*	
15:10	Discussion	
15:30	Break	
15:50	Plenary Session (Cont.) (Session Chair: Dr. Yasunari)	
	Science Overview: (WG-IV) Long-term Climate Variability and Precipitation	
	Dr. Nobuo Yamazaki *"Trend of Rainfall and Its Extreme in Asia"*	
16:10	Dr. Vikram Mehta *"Long-term Climate Variability and Precipitation in the Asia-Pacific Region"*	
16:30	Discussion	
16:50	Project Overview _Coordinated Enhanced Observing Period (CEOP) of GHP	
	Dr. John Leese *"CEOP Overview except for A/A Regional Monsoon Experiment"*	
17:05	Prof. Toshio Koike *"CEOP-I in the Asia-Australia Monsoon Region"*	
17:20	Discussion	
17:45	Photo Taking	
17:55	Adjourn	
18:00 – 20:00	Reception (Restaurant DAY NIGHT, Second floor, SEAVANS AMALL) Welcoming Remarks: Prof. Tetsuzo Yasunari Closing Remarks: Dr. William K. M. Lau	

Wednesday, November 17

9:00 a.m.	Breakfast (Room 1)
9:30	Brief Introduction of FRSGC
	Dr. Taroh Matsuno (Director-General of Frontier Research System for Global Change)
9:45	Plenary Session Charge to the Working Groups
	Prof. Yasunari, co-convener and Dr. Lau, co-convener
10:00	Working Group sessions (Each group will move to a designated room.)
	WG-I (Room 1: SEAVANS Meeting Room ,SEAVANS 1F,) Session Chair U.S.: Dr.Pielke Japan: Prof. Iwasaki
	WG-II (Room 2: JAMSTEC Tokyo Satellite Office, SEAVANS 7F) Session Chair U.S.: Dr. Wang Japan: Prof. Yasunari
	WG-III (Room 3: FRSGC Meeting Room, SEAVANS 7F) Session Chair U.S.: Dr.Petty Japan: Prof. Nakamura
	WG-IV (Room 4: FRSGC Prof. Yasunari's Office, SEAVANS 7F) Session Chair U.S.: Dr. Gruber Japan: Dr. Matsumoto
10:45	Break
11:00	Working Group sessions (continued),
12:30 p.m.	Lunch (see attached suggestions)
14:00	Working Group sessions (continued)

14:30	Break
14:45	Working Group sessions (continued)
16:00	Plenary Meeting for Status Reports from Working Groups (Room 1)
17:30	Adjourn
17:45	Chairman Meeting (Room 3)

Thursday, November 18

9:00 a.m.	Breakfast (Room 1)
9:30	Working Group Sessions (Each group will move to the same room as the second day.)
10:45	Break
11:00	Working Group Sessions (continued) Ad Hoc CEOP Coordinating Group Meeting (Room V: JAMSTEC Tokyo Satellite Office, 7F)
12:00p.m.	Lunch (see attached suggestions) Co-convenor Luncheon Meeting (Room_)
13:30	Plenary Meeting for Working Group Reports and Co-convenor's Reports (Room 1)
14:30	Break
15:00	Working Group Sessions for the final WG Report (Each group will move to the same room as the second day.) Co-convenor Meeting for the final Co-convenor's Report (Room 2)
17:00	Plenary Meeting for approval of the reports (Room 1)
18:00	Adjourn Closing Remarks: Dr. Taroh Matsuno (Director-General, Frontier Research System for Global Change)

Working group sessions will include informal presentations by up to 6 speakers (but up to the discretion of the chair). Presentations will not exceed 10 minutes per person.
This agenda is subject to change.

Lunch Information:
There are many restaurants in the SEAVANS AMALL and the Toshiba Building located across the street. You can find a good variety of food—Chinese, Japanese, Italian and Burger King.
Star Board, on the second floor of the SEAVANS AMALL is cafeteria style and serves curry, pasta, etc for only 1000 yen.
Day Night is a western style restaurant also on the second floor of the SEAVANS AMALL.
Wako is a tonkatsu (Japanese style fried pork) restaurant on the first floor of the Toshiba Building.

Appendix B: Abstracts of Science Overviews

Meso-scale Characteristic of the Intense Rainfalls in the East Asia Summer Monsoon

Kozo Ninomiya
Center for Climate System Research, University of Tokyo

The intense convective rainfalls occur frequently over the Japan Islands and the adjacent regions in the summer monsoon season. The intense rainfalls tend to occur in association with the development of meso-scale precipitation systems in the Meiyu / Baiu frontal zone.

The intense rainfall events in East Asia exhibit complicated "multi-scale features", since circulation systems of many scales (global, synoptic, meso-_, meso-_ and Meso-_scale) are interacting with each other. Variations of the Asian monsoon and the North Pacific subtropical anticyclone with various time-scale have strong influence on the occurrence of the intense rainfalls event.

The rainfalls of these meso-scale precipitation systems shows typical concentration within an area of ~100 km square and in a time span of 3 - 10 hours. The quasi-periodic occurrence of the precipitation peaks with the interval of 1-3 hour is usually seen in an intense rainfall event. The maximum precipitation in these regions for the duration of 3-12 hours is comparable to the maximum value recorded in the world, while the maximum precipitation in the shorter (1 hour) and longer (2 day) duration are considerably smaller than the world records.

The recent observations, however, indicate frequent occurrence of the intense rainfalls concentrating in the shorter duration (1 hour). It is an interesting problem to examine the influence of the global warming on the nature of the circulation systems and precipitation systems in the East Asia summer monsoon.

Mesoscale Systems, Severe Storms, and Heavy Precipitation

Roger M. Wakimoto
Department of Atmospheric Sciences_
UCLA

The presentation will focus on only a subset of important problems related to deep convection, heavy precipitation and winter storms. This will include mesoscale convective systems (MCSs), quantitative precipitation forecasts (QPF) in areas of complex terrain, convection initiation, tornadogenesis, and frontal structure within extra tropical cyclones. Nearly half of the significant precipitation episodes in the United States (24-hr amounts >0.5 in) are associated with extratropical cyclones while the other half is associated with MCSs. The forcing mechanisms for MCSs are generally poorly resolved by the numerical models used for guidance. This problem remains a challenging problem for operational forecasts of heavy rain events.

It has been well-established that MCSs are characterized by convective and stratiform regions. While the convective regions are often accompanied by strong wind gusts, hail, and the most intense precipitation rates; it has been the stratiform region that has garnered the most interest in recent years. One of the impressive features within this region is the Mesoscale Convective Vortex (MCV). MCVs can persist well after the system has dissipated and can initiate secondary convection. It has also been_hypothesized that MCVs play a role in hurricane formation.

There has been a growing interest in understanding the processes that lead to the initiation of convection during the warm season when upper-level baroclinic forcing is relatively weak. Recent studies have shown the importance of convergence boundaries as spawning grounds for convection that, at first glance, appear random. Major improvements in these forecasts appear to be hampered by accurate measurements of water vapor. Concerted efforts are underway to improve these measurements both_regionally and globally.

Rotating storms, referred to as supercells, produce most of the violent tornadoes. Surprisingly, it is only a small fraction of these storms (<15%) that produce tornadoes resulting in high false alarm rates. Recent results have also shown that the non-tornadic storms can look remarkably similar to their tornadic counterparts. Accordingly, the triggering mechanism for tornadogenesis has remained elusive.

Modeling Land Surface-atmosphere Interactions in East Asia

Yongkang Xue
Department of Geography
University of Maryland

Hydrology system in East Asia exhibits very high spatial and temporal variability. For example, observational precipitation data (Weng et al., 1999) and river runoff data have shown strong interannual and inter-decadal variations in East Asia, in particular, a dramatic change during the 1970s. Substantial effort has been made to model the impact of land surface processes, especially land cover changes, on water and energy balance at the land surface. This type of study is important given the dramatic increase in population and water demand in the East Asian region.

In the past decade, biosphere models, which include vegetation canopy, have been developed. Sensitivity studies with coupled biosphere-atmosphere models have been conducted to investigate the influence of land surface processes on precipitation and the surface hydrology system. In one numerical experiment with the coupled COLA GCM and SSiB vegetation model, after the degradation of the Mongolian and Inner Mongolian grasslands, a reduction in evaporation is accompanied by reduced rainfall and increased surface temperature in the degraded area. In addition, rainfall anomaly extends far to the south of the degraded area. The spatial distribution of the East Asian monsoon is changed. These features are consistent with the observed climate anomalies. The results from this study indicate that degradation of the grassland could have a substantial impact on the regional climate, and other important features of the East Asian summer monsoon. In another numerical experiment with the same model, different snow covers over the Eurasian continent produce different summer monsoon responses (Vernekar et al., 1996).

Efforts have also been made to improve the prediction by using more realistic land surface model and land information. A newly developed global vegetation map, based on the NOAA/NASA pathfinder AVHRR 1-km land data set, is introduced to the NCEP GCM/SSiB model. Using a coupled NCEP GCM/SSiB and an original NCEP GCM (with a two-layer soil model), we have integrated the models for 4 months from May 1987 through August 1987 with different initial conditions. The most substantial differences between the original NCEP GCM and the NCEP GCM/SSiB are the simulations in the monsoon regions. For example, in the original NCEP GCM, the monsoon onset in East Asia in May is too strong and the rainfall area approaches too far to the north, whereas the NCEP GCM/SSiB correctly simulates the monsoon=s onset.

Research has been conducted to further improve the modeling of precipitation, cloud, and hydrology system. Because the land data are crucial in the understanding of the East Asian hydrology and in validating the model, a great deal of effort has been made to collect and analyze the land data. In addition to the vegetation data mentioned above, soil moisture data in Russian, China, and Mongolian has been collected. Temporal and spatial scales of its variability are analyzed (Robock et al., 1995, Entin, 1999). Exploratory study has also been conducted to investigate the Chinese river runoff to understand its variability. These data are also important for validating land surface models.

Studies have also been conducted to improve parameterizations in GCMs. Due to the importance of snow processes in Asian monsoon, a three layer snow scheme has been developed based on up to date comprehensive and complex snow cover schemes. In the development, substantial simplification and improvement are achieved. For example, volumetric specific enthalpy instead of temperature is used as the prognostic variable, which simplifies the formulations in phase change processes and reduces the computational procedures. This snow scheme has been coupled with SSIB to improve the SSIB prediction potential in snow cover regime. Long term Russian field snow data have been used to validated the model.

Cloudiness and cloud radiative forcings are important sources of uncertainty in climate studies. A state-of-the-art prognostic cloud microphysics, McRAS, has been developed to improve cloud prediction in GCMs (Sud and Walker, 1999). Its parameterizations contain physically based algorithms for cumulus, stratiform, and boundary layer clouds. The key algorithms in McRAS that influence the simulation of the fields of precipitation, condensation heating, and cloud radiative forcing have been evaluated using the GATE Phase III data in the NASA GEOS II GCM (Sud and Walker, 1999 a & b).

The Development of Global Land-Atmosphere Coupled Model under NWP Environment with International Science Community

Ken-ichi Kuma
Numerical Prediction Division, Japan Meteorological Agency

The global model at JMA is a multi-purpose model to cover various time scales from short-range weather forecast to climate prediction. This short report explains the importance of the international science community and NWP environment to develop the high performance global model.

We have developed the prognostic cloud water scheme. We have computed the single column model (SCM) version of this scheme under the framework of GCSS SCM experiment. Compared with other SCMs, our model has the strong cooling bias in the upper troposphere, although the difference of cloud water content is not recognized. After many sensitivity studies, we found the radiative heating rate is very sensitive to the effective radius of the cloud ice. Increasing the radius such that it fits to the observational result, we can finally reduce the cooling bias.

Under NWP environment, we can directly compare the model output with the observation. Such comparison gives us valuable information as to the model performance and the way to improve it. For example, JMA receives Typhoon track forecast data from major NWP centers and compares these results with the actual Typhoon track forecast. Before 1996, the typhoon track forecast with JMA model was not as good as the other NWP centers. In order to improve the forecast, we developed the cumulus parameterization with Arakawa – Schubert concept. With the new cumulus scheme, we achieved the significant improvement for Typhoon track forecast.

Cloud scheme and land surface scheme are critical components for both NWP and climate models. The improvement of these processes requires the validation of the processes. Physical processes must be verified under the proper large scale forcing. If we verify the processes after the long time integration, the large scale forcing itself is already biased to its model climate. Thus, it is critical to verify the model under NWP environment, short range forecast starting from the analysis based upon the observation. Another benefit of NWP environment is the direct comparison between model and observation.

It is concluded that the development of high performance model requires NWP environment as well as the link to the international science community.

Current Issues on ENSO- Monsoon Interactions

Tetsuzo Yasunari
Frontier Research System for Global Change, Tokyo
Institute of Geoscience, University of Tsukuba, Ibaraki

The recent ample evidences have shown various observational aspects of the ENSO (El Niño/Southern Oscillation) and the Asian/Australian monsoon interaction (e.g., Yasunari, 1990; 1991, Webster and Yang, 1992, Lau and Yang, 1994). Some modeling studies also have suggested the role of Asian summer monsoon coupled with the east-west circulation over the tropical Pacific in determining anomalous state of the coupled ENSO/monsoon system. However, some major questions is still remained unresolved, e.g., when, where and how an anomalous state of this coupled system changes to another in the seasonal cycle of the tropics, what process modulates the biennial oscillation of this system, and how this system interacts with climate variability of decadal or longer time scales.

In this talk, I will overview the current understanding of the ENSO/monsoon system, and a new view of the "predictability barrier" of this system will be proposed, which is likely to appear in the midst of the Asian monsoon season, rather than in northern spring or pre-monsoon seasons (Ai Likun and Yasunari, 1999). Associated with this seasonal phase-locking, implication of some monsoon indices to the interannual variability of the system will also be discussed, with the emphasis of important role of the atmosphere/ocean interaction in the western Pacific in northern summer (Yasunari et al., 1999).

Finally, the long-term modulation of the ENSO-Asian monsoon relationship will briefly be interpreted for the period of the past 100 years from 1890 to 1990's, by applying lead/lag correlations of the all-India Monsoon Rinfall (IMR), Southern Oscillation Index (SOI) and the NAO index in the seasonal cycle. The results suggest that the interannual variability, including the biennial oscillation, of the ENSO/Asian monsoon system shows strong modulation of the inter-decadal variation, which is likely to be closely associated with the NAO polarity change and the amplitude modulation of IMR with the same time-scale.

These observational evidences strongly suggest us further studies on multi-scale interactions of the Asian monsoon and the ENSO, particularly in the seasonal cycle.

The Indian Ocean and the Monsoon as a Coupled Ocean-atmosphere Phenomena: The Modulation of Monsoon Precipitation

Peter J. Webster
Program in Atmospheric and Oceanic Sciences
University of Colorado

The traditional view of the Asian-Australian monsoon system is a planetary scale circulation driven by large-scale heating gradients occurring between the summer and the winter hemispheres. In this model, the ocean appears as a passive entity forced by the winds produced by the latitudinal heating gradient. This model fails because the heat budget of the Indian Ocean and the observed changes in sea surface temperature throughout the entire year cannot be explained by local processes. Furthermore, the Indian Ocean region is subjected to large scale and strong external forcing from such phenomena as the El Niño-Southern Oscillation (ENSO) phenomena and variations over the Asian land mass by changes in albedo and ground surface water associate with (possibly stochastic) variability in winter and spring snowfall. Yet, despite these influences, the monsoon rainfall (measured here in terms of Indian rainfall) is remarkably stable from one year to the next compared to other regions of the globe which are also forced by the same phenomena. In addition, there is recent evidence that the Indian Ocean exhibits strong and reoccurring oscillations. This Indian Ocean mode, or Indian Ocean dipole, appears as a coupled ocean-atmosphere phenomena of considerable influence and magnitude.

We present a different view of the Indian Ocean-monsoon system and one that is regulated through a negative feedback system between the ocean and atmosphere. We show modeling and empirical evidence that the magnitude monsoon is held within relatively tight limits. The coupled ocean-atmosphere feedback system appears to operate on intraseasonal, annual and interannual timescales. Anomalies in the large scale forcing of system are modulated through the ocean atmosphere feedback system. Differences in the magnitude of the monsoon are probably the result of differences in the character of intraseasonal oscillations which can probably be considered as chaotic oscillations occurring within one season.

Satellite-based Global Precipitation Data Sets at Monthly and Finer Time Scales

Robert Adler
NASA/Goddard Space Flight Center

A new 20-year, monthly, globally complete precipitation analysis has been completed as part of the World Climate Research Program's (WCRP/GEWEX) Global Precipitation Climatology Project (GPCP The global, monthly, 2.5° x 2.5° latitude-longitude product utilizes precipitation estimates from low-orbit microwave sensors (SSM/I) and geosynchronous IR sensors and raingauge information over land. The low-orbit microwave estimates are used to adjust or correct the geosynchronous IR estimates, thereby maximizing the utility of the more physically-based microwave estimates and the finer time sampling of the geosynchronous data.

The 20-year climatology of the Version 2 GPCP analysis indicates the expected features of a very stong Pacific Ocean ITCZ and SPCZ with maximum 20-year means approaching 10 mm/day. A similar strength maximum over land is evident over Borneo. Weaker maxima in the tropics occur in the Atlantic ITCZ and over South America and Africa. In mid-latitudes of the Northern Hemisphere the Western Pacific and Western Atlantic maxima have values of approximately 7 mm/day, while in the Southern Hemisphere the mid-latitude maxima are located southeast of Africa, in mid-Pacific as an extension of the SPCZ and southeast of South America.

In terms of global totals the GPCP analysis shows 2.7 mm/day (3.0 mm/day over ocean; 2.1 mm/day over land), similar to the Jaeger climatology, but not other climatologies. Zonal averages peak at 6 mm/day at 7°N with mid-latitude peaks of about 3 mm/day at 40-45° latitude. Poleward of 45° the GPCP analysis shows larger zonally-averaged values than most previous satellite-based estimates, although the values are similar to the Jaeger climatology. Comparisons with recent estimates based on TRMM indicate the TRMM estimates about 10% larger than GPCP with significant regional variations.

Variations in both tropical and mid-latitude rainfall related to ENSO will be shown along with ENSO-related variations of tropical cyclone rainfall.

Preliminary results from finer scale global estimates will also be shown for the 1997-1998 period, along with their application to analysis of the initiation of the recent ENSO event.

Microwave Remote Sensing of Snow, Soil Moisture, Surface Temperature and Rain

Toshio Koike
Frontier Research System for Global Change, Tokyo
Department of Civil Engineering, University of Tokyo

Microwave remote sensing can directly measure the dielectric properties which is strongly dependent on the liquid water content. The longer wave length is one of the advantages of microwaves. It is long enough to reduce the scattering effect of cloud particles and to make microwave sensors a useful all-weather sensor. The wave length in the microwave region has sensitivity to the scattering effect of snow grains and leaves. Microwave remote sensing has potential of the measurement of snow water equivalent and water content of vegetation. By using higher frequency channel, scattering effects of rain drops can also be detected. The independence of sun as a source of illumination is also one of the important reasons for using microwaves. We can obtain the data even in night. This advantage is more important in the case of non-sunsynchronous observation.

The microwave brightness temperature observed by satellites is expressed by the radiative transfer equation which consists of the land surface radiation attenuated by vegetation and precipitation fields, the radiation from vegetation attenuated by precipitation fields, and the radiation from precipitation fields.

The snow algorithm is based on the relationship between the land surface radiation and snow water equivalent which is obtained by a radiative-transfer theory based on a scattering dielectric layer over a homogeneous half-space. The total land surface brightness temperature is the sum of the direct component, the reflected sky radiation and the thermal radio emission from snowpack and soil, and the diffuse component, the radiation scattered from the direct field and diffuse field. Snow depth and physical temperature are estimated by inputting the observed brightness temperature at two different frequencies into a look-up table which is simulated based on the radiative transfer equation by assuming snow grain size and snow density and by neglecting the effects of vegetation and precipitation fields.

In the soil moisture algorithm, vegetation is considered as an absorption and radiation layer on skin soil characterized by dielectric constant which depends on soil moisture. To incorporate the effects of surface roughness, the reflectivity is calculated by using a polarization-mixing parameter and a roughness parameter. Two indices, Soil Wetness Index and Polarization Index, in which effects of physical temperature are removed, are introduced to estimate land surface soil moisture and water content of vegetation. A look-up table which shows the relationship between soil moisture, water content of vegetation and the two indices is calculated by the radiative transfer model. Soil temperature is estimated by inputting the estimated soil moisture and water content of vegetation into the radiative transfer model.

The precipitation algorithm is basically same as the soil moisture algorithm. Precipitation field is modeled as a scattering extinction layer over skin soil without vegetation cover. To make the algorithm simple, the effect of precipitation filed is taken account at higher frequency but not at lower one.

The algorithms were applied to the TRMM Microwave Radiometer (TMI) and validated by using the ground data obtained in the Tibetan Plateau. The estimated snow, soil moisture, surface temperature, water content of vegetation and rain patterns corresponded reasonably to the observed ones.

Trend of Rainfall and Its Extreme in Asia

Nobuo Yamazaki
Meteorological Research Institute, Japan

Global warming is expected to enhance hydrological cycle due to increased water vapor amount in the low-level atmosphere. Consequently rainfall extremes causing flood and drought might occur more frequently. A hundred-year record of mean annual and summer rainfall in Asian monsoon region does not show a clear increasing trend pattern.

There is an enhanced period of annual rainfall for 1940 to 1960 in India, China and Japan. Extreme rainfall events in China and Japan occur more frequently in this period. Alternatively there are negative trends of the rainfall and the extremes in China and Japan during the last 50 years.

To see how large scale fields has changed in the past 40 years, the NCEP/NCAR reanalysis data are used to examine linear trend of temperature, geopotential height and circulation fields. There exists significant summertime mean low-level cooling trend (typical rate is 1.5 degree/40years) from west China to north China, in contrasted to wintertime warming trend. Corresponding increase of summer-time mean low-level pressure is observed in the whole Asian continent east of 60E and south of 60N. Consistent with these trends, there is weakening of low-level cyclonic circulation around the Asian continent. Particularly, weakening of low-level westerly in South Asia and that of southerly in East Asia are prominent. Therefore, these trends such as cooling over the Asian continent and weakening of the westerly signify weakening of the Asian monsoon in the past 40 years.

How reliable is the trend of the analysis data? The cooling trend in northwest China is also observed in the surface temperature. Horizontal distribution of summer rainfall trend in Asia during the last 50 years generally shows negative trend over South Asia between 10N and 20N including India and the Indochina Peninsula, south and east China, and Japan. Positive trend is seen in the equatorial Indian Ocean and the Western Pacific including Philippines. The regions of these positive trends well correspond to those of low-level wind shear or convergence. Main features of the rainfall trend are consistent with the trend of low-level circulation pattern derived from the reanalysis data.

The weakening of low-level westerly is also consistent with the well-known warming trend of SST over the Indian Ocean. This warming might be correlated with increasing trend of low-level specific humidity from south India through Philippines.

In summary, long term surface data as well as the NCEP/NCAR reanalysis data suggest that there are the period of the enhanced rainfall and monsoon activity around the nineteen fifties or the trends of the decreased rainfall and weakening in the monsoon activity in the last 40 years. If this period or trend is confirmed to be a part of natural variability and the effect may be isolated, then the resultant trend pattern of the rainfall and the extreme would be different from that obtained by the simple linear method.

Long-term Climate Variability and Precipitation in the Asia Pacific Region

Vikram M. Mehta
Earth System Science Interdisciplinary Center
University of Maryland

Observed characteristics of Asia-Pacific climate variations and associated precipitation variations at decadal and longer timescales will be reviewed. Among them are the Pacific decadal oscillation, vacillations in the Indo-Pacific warm pool, the Indian monsoon rainfall, the ENSO phenomenon and its impact on Asia-Pacific precipitation, and rainfall variations over North America. The possible/likely influence of solar irradiance variations and anthropogenic climate change on Asia-Pacific precipitation variations at decadal and longer timescales will also be reviewed. A program to 'mine' already-collected observations and model these long-term climate variations to understand the mechanisms of these variations and assess their predictability will be outlined.

Appendix C: List of Acronyms

ADEOS-II	Advanced Earth Observing System II (Japan)
AGCM	Atmospheric General Circulation Model
AMIP	Atmospheric Model Intercomparison Project
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Sounding Radiometer- EDS/PM
ATMOS	Atmospheric Trace Molecules Observed by Spectroscopy
BAHC	Biospheric Aspects of the Hydrological Cycle
CEOP	Coordinated Enhanced Observing Period
CLIVAR	Climate Variability and Predictability Program
CMAP	CPC-Merged Analysis of Precipitation
CMIP	Coupled Model Intercomparison Project
CMT	convective momentum transport
CPC	Climate Prediction Center
CRM	Cloud Resolving Model
ECMWF	European Centre for Medium Range Weather Forecasting
ENSO	El Niño Southern Oscillation
ERA	ECMWF Reanalysis
ERA-40	ECMWF 40-year Reanalysis
FORSGC	Frontier Observing Research System for Global Change (Japan)
FRSGC	Frontier Research System for Global Change (Japan)
GAME	GEWEX Asian Monsoon Experiment
GCM	General Circulation Model
GCSS	GEWEX Cloud System Study
GEWEX	Global Energy and Water Cycle Experiment
GHP	GEWEX Hydrometeorology Panel
GMS	Geostationary Meteorological Satellite (Japan)
GPCP	GEWEX Precipitation Climatology Project
GPM	Global Precipitation Mission
GSWP	Global Soil Wetness Project
IGBP	International Geosphere-Biosphere Programme
IPRC	International Pacific Research Center
ITCZ	Inter-Tropical Convergence Zone
JAMSTEC	Japan Marine Science and Technology Center
JASMINE	Joint Air-Sea Monsoon Interaction Experiment
NASA	National Aeronautics and Space Administration (US)
NASDA	National Space Development Agency (Japan)
NCAR	National Center for Atmospheric Research (US)
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration (US)
NSF	National Science Foundation (US)
PILPS	Project for Intercomparison of Landsurface Parameterization Schemes
RADAR	Radio Detection and Ranging
SCSMEX	South China Sea Monsoon Experiment
SEAVANS	Sea Advance
SSM/I	Special Sensor Microwave Imager
STA	Science and Technology Agency (Japan)
TRMM	Tropical Rainfall Measuring Mission
USGCRP	U.S. Global Change Research Program (US)
WCRP	World Climate Research Program
WGSIP	Working Group for Seasonal to Interannual Prediction

Appendix D: List of Participants
(Alphabetical order)

List of Participants
(Japan)

Kazumasa Aonashi
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